Long-term orbital environment prediction by orbital debris evolutionary model

Report Number: R22EG3105
Subject Category: Research and Development
URL: https://www.jss.jaxa.jp/en/ar/e2022/20862/

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Abstract

Increase of space debris is a problem for reliability of sustainable space activity. JAXA has researched space debris related technology for space debris mitigation and environmental remediation. The effectiveness of space debris countermeasures is evaluated based on the prediction of future orbital environment using the orbital debris evolutionary model (NEODEEM) jointly developed by JAXA and Kyushu University.

Ref. URL: http://www.kenkai.jaxa.jp/research/debris/debris.html

Reasons and benefits of using JAXA Supercomputer System

NEODEEM predicts the situation of over 200 years orbital propagations of more than 20000 elements and orbital events by using Monte-Carlo method (evaluate the average of 100 runs). Therefore, JSS3 is used to reduce run time and to process a large amount of data. TOKI-RURI is used for compatibility with PC version (Linux, WINDOWS).

Achievements of the Year

As a part of the evaluation of the future orbital environment, the simulations of an large constellation's (LC) exploions were conducted using the Near Earth Orbital Debris Environment Evolutionary Model (NEODEEM). The impacts of a LC's explosions were assessed focusing on the number of explosions, explosion altitude and scaling factor which indicates the extent of explosions (Fig. 1). The evaluations of debris indices which assesses the environmental impacts of spacecraft or missions were also conducted in order to propose the effective indices in both short and long term (Fig. 2). These results are used to measure the effectiveness of debris mitigation, and also used as a basis for discussing international rules.

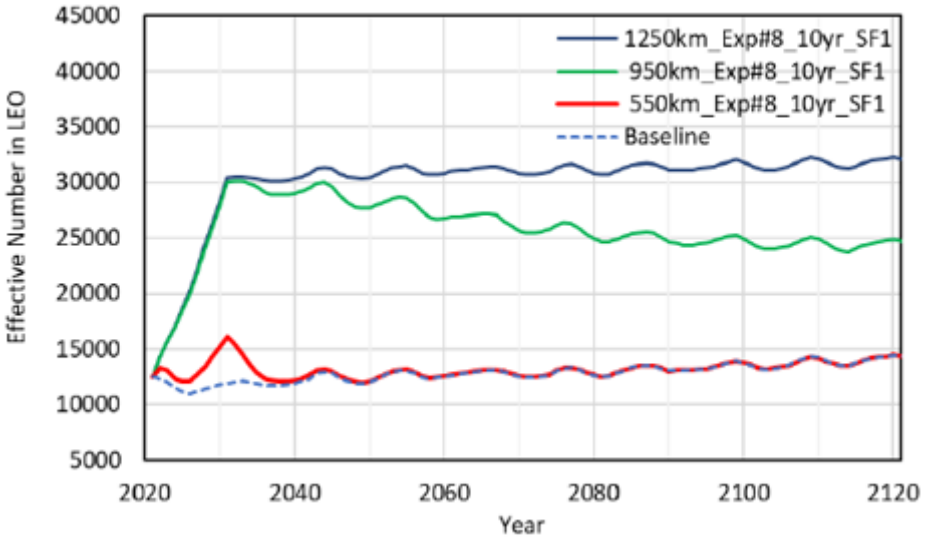

Fig. 1: The effective number of objects in LEO with the explosion altitude of 550, 950, and 1250 km

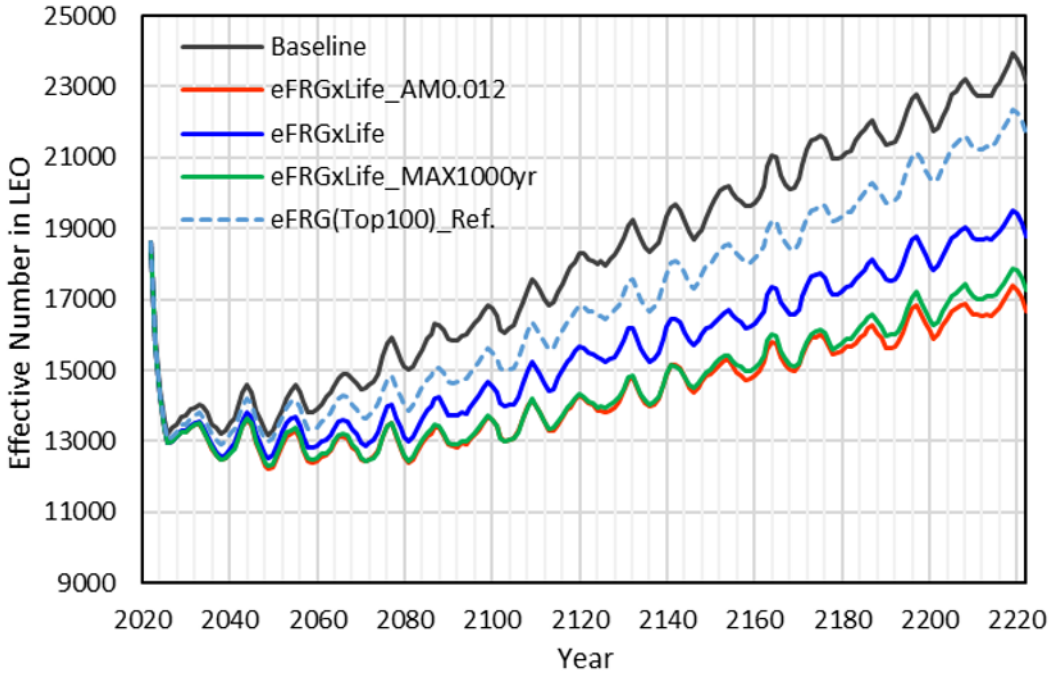

Fig. 2: Predictions of the effective number of objects in LEO for 200 years with and without active debris removal of each top 100 objects

Publications

- Peer-reviewed papers

Satomi Kawamoto, Nobuaki Nagaoka, Yasuhiro Kitagawa, Ryusuke Harada, Toshiya Hanada, Considerations on the lists of the top 50 debris removal targets, Journal of Space Safety Engineering, https://doi.org/10.1016/j.jsse.2022.05.006

- Non peer-reviewed papers

Ryusuke Harada, Satomi Kawamoto, Nobuaki Nagaoka, and Toshiya Hanada, The Imapct Assessment of Accidental Explosions of Large Constellations on Low Earth Orbit, IAC 2022 in Paris

- Oral Presentations

1. Nobuaki Nagaoka, Satomi Kawamoto, Ryusuke Harada, Yasuhiro Kitagawa, and Toshiya Hanada, Analysis of Orbital Debris Envirionment Using Debris Evolutionary Model, 10th Sapce Debris Workshop in Chofu

2. Ryusuke Harada, Satomi Kawamoto, Nobuaki Nagaoka, and Toshiya Hanada, Astudy of Utilization and Formulation of Space Debris Index, 10th Space Debris Workshop in Chofu

Usage of JSS

Computational Information

Process Parallelization Methods	Assigning Monte-Carlo runs with same initial conditions to multiple cores
Thread Parallelization Methods	N/A
Number of Processes	20 - 30
Elapsed Time per Case	12 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.19

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	0.00	0.00
TOKI-ST	1,534,766.55	1.53
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	3,672.76	0.25
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	35.00	0.03
/data and /data2	350.00	0.00
/ssd	350.00	0.05

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	27.40	0.12

*1: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage*2 (%)
ISV Software Licenses (Total)	0.00	0.00

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.